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PRELIMINARY MINERALOGICAL INVESTIGATION OF Pt-Pd-BEARING SAMPLES FROM RUTLEDGE LAKE, NORTHWEST TERRITORIES

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SUMMARY

Six samples from Rutledge Lake, Northwest Territories, were examined mineralogically to determine, in particular, the distribution of the platinum-group elements and gold. No platinum-group minerals were found, but Pd and Pt were determined analytically to occur as trace amounts in cobaltite (CoAsS) and Pd only in melonite ($NiTe_2$). These findings do not explain the high Pt content reported for one sample, but are understandable with respect to the Pd contents. A single 2.5 micrometre grain of native gold was found included in chalcopyrite in one sample.

Copper in the samples occurs as chalcopyrite ($CuFeS_2$) and when present, for most samples, is potentially recoverable by conventional mineral processing. On the other hand, Ni would not be easily recovered by conventional processing as it occurs largely as a solid solution in pyrrhotite (0.26-0.41wt.%), as very fine-grained inclusions of pentlandite, $(Fe,Ni)_9S_8$, or violarite, $(Fe,Ni)_3S_4$, within pyrrhotite or as a solid solution in marcasite. Unusually high Co contents (about 2 wt.%) were found in pyrite in one sample.

The rocks represent many lithologies of high amphibolite metamorphic grade. These range from various gneissic varieties to deformed sulphide-rich mafic rocks.

INTRODUCTION

Five drill core samples and one hand sample were received on 10th November, 1986 from Trigg, Woollett, Olson Consulting Ltd., 10504-103 Street, Edmonton, Alberta T5H 2V4. The samples came from their Rutledge Lake project (Enexco International Limited) in the Northwest Territories, 225 km south-east of Yellowknife. CANMET agreed to study the samples mineralogically with a view to describe/determine:

1. The habit, textures, and characteristics of the sulphide minerals present. What are the sulphides or metallic minerals visible optically or to the naked eye?

2. Presence of platinum-, palladium- or gold-bearing minerals especially in specimen 6R018003x?

3. Paragenetic relationship between sulphides, silicates and metallic minerals.

4. Comments of genesis.

SAMPLES AND METHODS OF ANALYSIS

The six samples received, together with drill logs were:

Sample	Type	Cu*	Ni*	Ag*	Au**	Pt**	Pd**
6R018003X	core	1040	620	0.3	55	1250	10
6R015017X	core	1700	1640	0.6	85	<50	35
6R007005X	core	n/a	n/a	n/a	n/a	n/a	n/a
6R007014X	core	830	3200	15.0	15	<50	50
6R01002X	core	n/a	n/a	n/a	n/a	n/a	n/a
11020W-C	hand	n/a	n/a	n/a	n/a	n/a	n/a

*ppm **ppb

Polished sections were made of all samples and studied by reflected

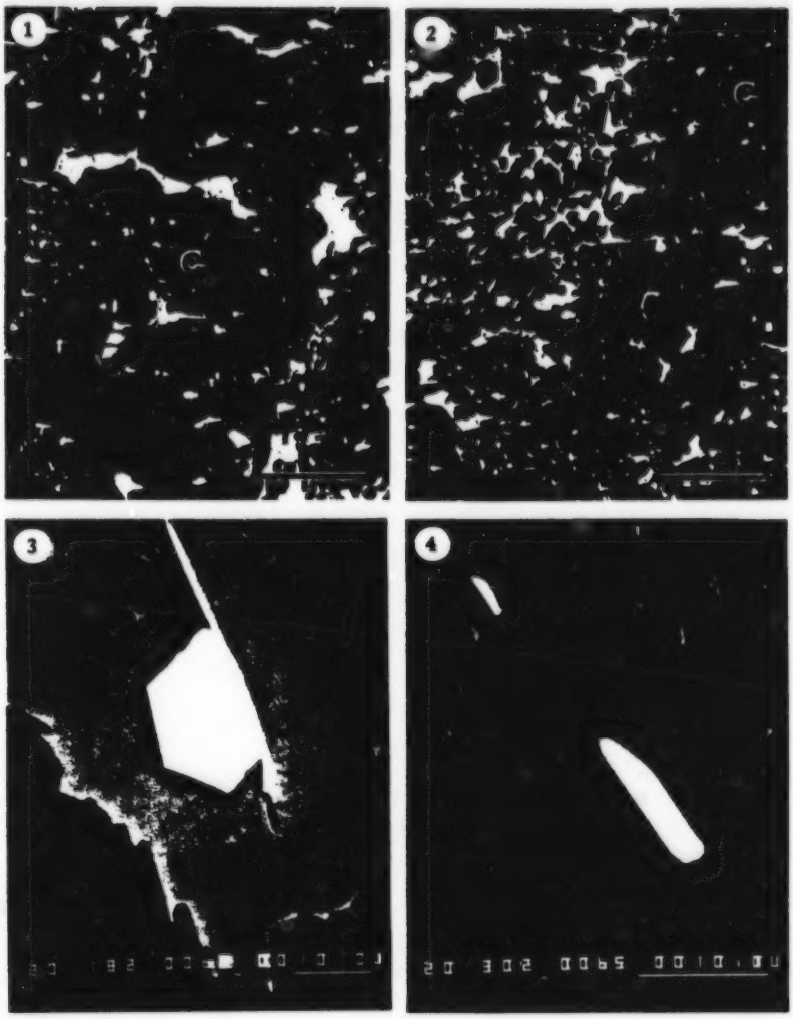
light microscopy. Follow up work to confirm identification of the minerals and for semi-quantitative and quantitative analysis were done on selected grains by scanning electron microscopy (SEM), electron microprobe (EMP) and X-ray diffractometry (XRD). Unanticipated difficulties developed in studying separates of sample 6R018003X which were subsequently submitted to the chemical laboratory for some precious metal assays. In addition to SEM photomicrography, low-magnification optical photographs were also taken in order to display the macroscopic textural details.

RESULTS

Sample 6R018003X

A cordierite-sillimanite-hercynite rock containing about 10% sulphides and approximately 1% intergrown ilmenite-rutile. (Figs. 1,2). Coarse (up to 200 micrometres thick) books of graphite are conspicuous in both silicates and sulphides and the cordierite is partly altered to chlorite, especially at its contact with sulphides. The sulphides and the ilmenite-rutile grains occur conformably between silicates with the exception of a few instances of sulphide veins and fine intergrowths in silicates.

The principal sulphide is pyrrhotite (both monoclinic and hexagonal varieties) with a Ni content ranging between 0.26 to 0.36 wt.% (5 grains) and with no Co detected (MDL=0.02 wt.%). Chalcopyrite is the second-most abundant sulphide, occurring mostly as >40 micrometre grains in pyrrhotite. Pentlandite occurs as a trace constituent, occurring as flame-like lamellae in pyrrhotite (typically <20 micrometres wide) and is sometimes partly to



Figs. 1,2. Cordierite (C), sillimanite (S), hercynite (H) with sulphides (white). (6R018003x, optical photomicrographs, scale-0.25cm).

Fig. 3. Cobaltite crystal with attached molybdenite lamellae included in pyrrhotite. Black area is hercynite. (6R018003x, SEM photomicrograph with scale in micrometres).

Fig. 4. Loellingite inclusions in hercynite. (6R018003x, SEM photomicrograph).

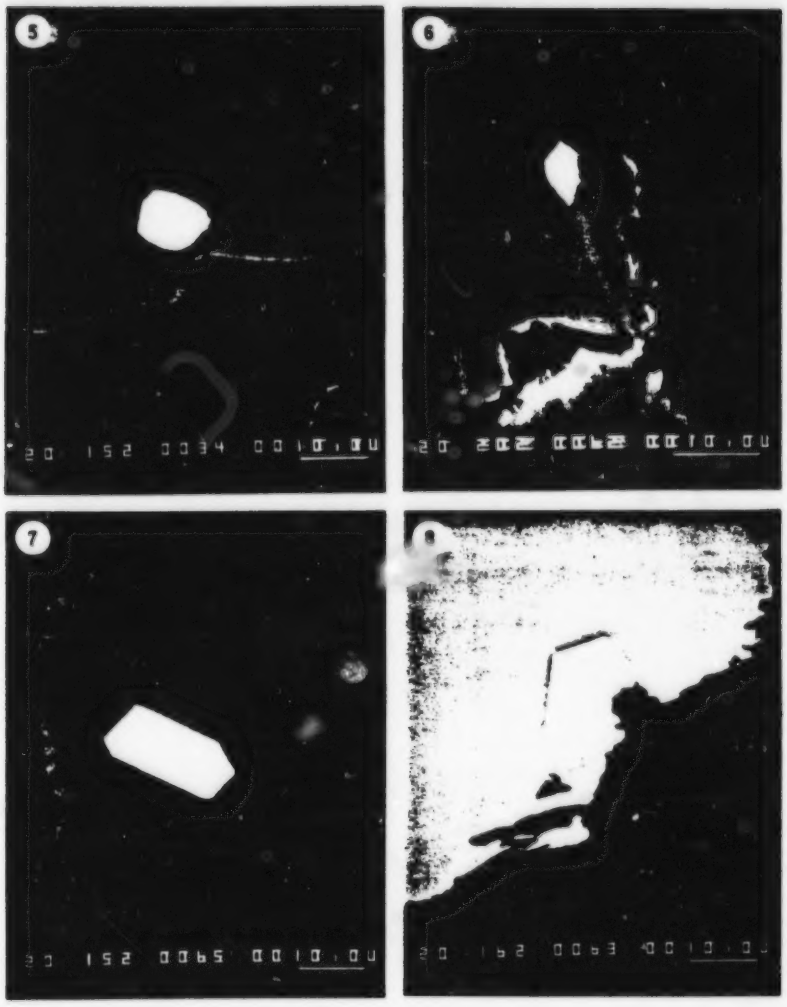


Fig. 5. Pd-bearing melonite inclusion in pyrrhotite. (6R018003x, SEM photomicrograph).

Fig. 6. Altaite inclusion at a pyrrhotite (left) and chalcopyrite (right) boundary in contact with hercynite (extreme right). (6R018003x, SEM photomicrograph).

Figs. 7,8. "Small" cobaltite grains included in pyrrhotite: in contact with chalcopyrite (7) and in contact with silicates (8). Analysis of grain in Fig.7 gave up to 0.11% Pd. (6R018003x, SEM photomicrographs).

completely altered to violarite. Arsenopyrite, cobaltite, molybdenite (Fig. 3), loellingite $FeAs_2$ (Fig. 4), melonite (Fig. 5), altaite PbTe (Fig. 6) and Bi-Te are rare to very rare constituents. Arsenopyrite and cobaltite occur as fairly large grains (100-150 micrometres) but cobaltite also occurs as smaller euhedral grains (up to about 20 micrometres) equally distributed in pyrrhotite and silicates (Figs. 3,7,8).

No platinum-group minerals (PGM) were found but platinum-group elements (PGE) were detected in cobaltite and melonite. Platinum and palladium were sought by EMP analyses in pyrrhotite, ilmenite, rutile, pentlandite and arsenopyrite but were not detected at minimum detection levels (MDL) of about 0.02 wt.% for Pd and 0.04 wt.% for Pt. In the case of cobaltite, Pd and Pt were only detected in the smaller grains (Table 1).

Table 1. Pd and Pt spot analyses in cobaltite.

Grain No.	Spot #	Association	Pd wt.%	Pt wt.%
4B	1	silicate	<MDL	<MDL
	2		<MDL	<MDL
6B	1	silicate	0.02	<MDL
	2		<MDL	<MDL
5B	1	pyrrhotite	0.09	0.12
	2		0.07	0.08
7B	1	pyrrhotite/ chalcopyrite	0.11	<MDL
	2		0.08	<MDL
	3		<MDL	<MDL
	4		<MDL	<MDL
8B	1	pyrrhotite	<MDL	<MDL
	2		<MDL	<MDL
9B	1	silicate	0.07	<MDL
12B	1	pyrrhotite	<MDL	<MDL

	2		0.03	<MDL
	3		0.03	<MDL
11A	1	pyrrhotite	0.03	<MDL
	2		0.03	<MDL
	3		0.04	<MDL
12A	1	pyrrhotite/ chalcopyrite	0.08	<MDL
	2		0.05	<MDL

MDL: Pd = 0.02 wt.%, Pt = 0.04 wt.%

A complete quantitative analysis was performed on one melonite grain (Table 2). The formula is :

$Ni_{0.86}Fe_{0.13}Co_{0.03}Pd_{0.04}Te_{1.93}\ Sb_{<0.01}Bi_{0.01}$.

Table 2. Electron probe analyses of melonite.

No.	Ni	Fe*	Co	Pd	Pt	Te	Sb	Bi	Totals
1	16.3	2.3	0.64	1.3	n.d.**	79.5	0.10	0.57	100.71
2	16.7	0.71	0.59	1.0	n.d.	79.6	0.12	1.7	100.42

(1) Grain 1, 8X10 micrometres, in pyrrhotite, sample 6R018003X. (2) Grain 2, 15X20 micrometres, at pyrrhotite/silicate boundary, sample 6R015017X.
* Fe contents probably due to secondary X-ray fluorescence.
** Not detected (MDL = 0.05 wt.%)

Sample 6R015017x

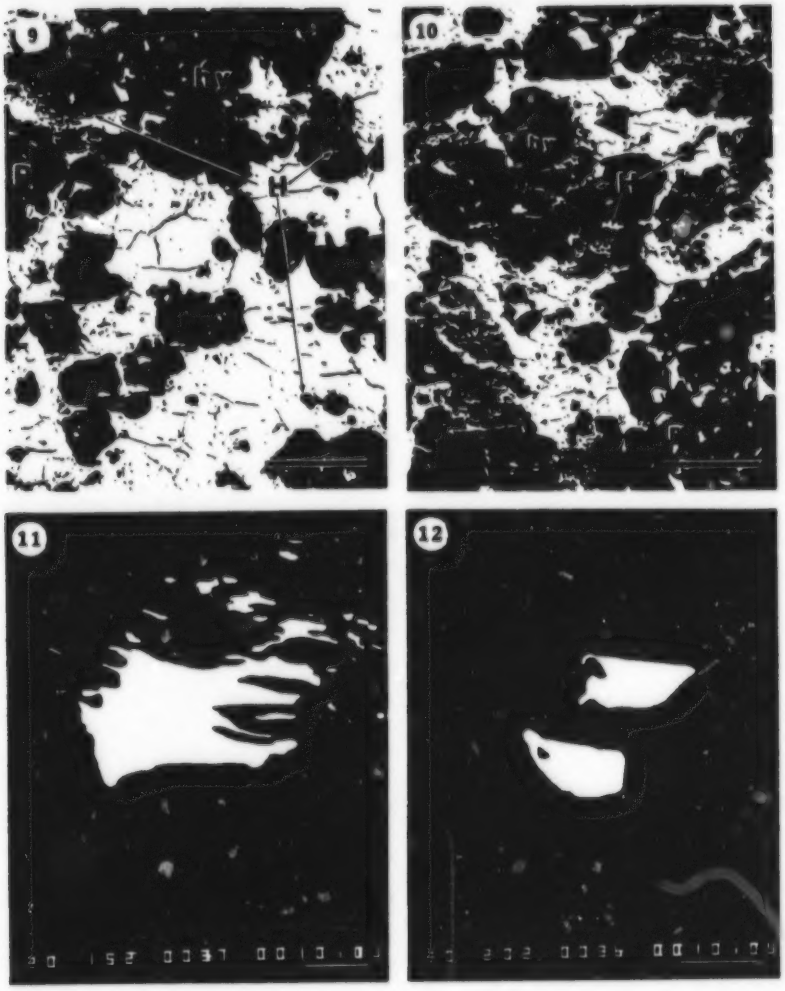
This rock contains nearly equal proportions of sulphides and silicates. Chromium-bearing hercynite is a minor constituent (<1% ?) and occurs as inclusions in silicates and pyrrhotite as well as at the pyrrhotite-silicate boundary. Hypersthene has been identified as the major silicate mineral, confirmation of the mafic nature of the rock, and a plagioclase (high Ca) is a subordinate constituent. Graphite is less frequent and occurs in books ranging to 200 micrometres thick. The principal sulphide is pyrrhotite and occurs

mainly intergranularly to the silicates (Fig. 9) but also as fracture fillings and replacement of silicates (Fig. 10). Four pyrrhotite grains were analysed quantitatively and proved to be the hexagonal variety with a Ni content of 0.40 wt.% and with no Co detected (MDL=0.02 wt.%). Chalcopyrite and violarite are next in abundance. Chalcopyrite occurs as inclusions in pyrrhotite, >20 micrometres for the most part. Violarite only occurs in pyrrhotite, forming complex intergrowths up to 100 micrometres which consist of an agglomeration of fine-grained crystals. Rare to very rare molybdenite, melonite (Figs. 11, 12), and cobaltite were also observed.

No PGM were found but Pd was detected in one melonite grain (Table 2). A single inclusion of native gold (2.5 micrometres) was observed in chalcopyrite but was not confirmed with the SEM.

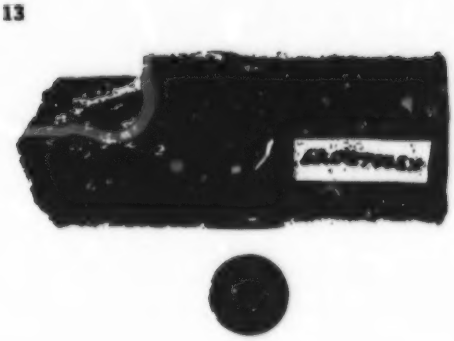
Sample 6R007005x

This sulphide-rich rock (approximately 60/40 sulphide/silicate) has a distinctive 4-cm diameter spherical and vuggy structure of uncertain origin (Fig. 13). Macroscopically, this rock is a breccia with a sulphide matrix (pyrrhotite) containing fragments of silicates as well as an occasional sulphide fragment. The polished section was prepared to include part of this structure, which largely consists of intergrown pyrite-marcasite (Figs.14,15), whereas pyrrhotite is the principal sulphide in the surrounding matrix. Some silicates were analysed semi-quantitatively and may also include hypersthene on the basis of chemistry. Rounded spinel grains (chromium bearing hercynite) occur in both sulphide facies, invariably exhibiting a peripheral alteration zone. Graphite is dispersed throughout the



Figs. 9,10. Principal sulphide is pyrrhotite (white), Cr-hercynite (H) is a minor phase, hypersthene (hy) is the major silicate and a plagioclase (P) is subordinate. (6R015017x, optical photomicrograph, scale=0.25 cm).

Figs. 11,12. Melonite (white) inclusions attached to pyrrhotite (grey, 11) all included in gangue (Si>>Mg>Fe>>Al) and attached to chalcopyrite (grey, 12) included in gangue (Si>Al =Mg,K).(6R015017x, SEM photomicrograph)



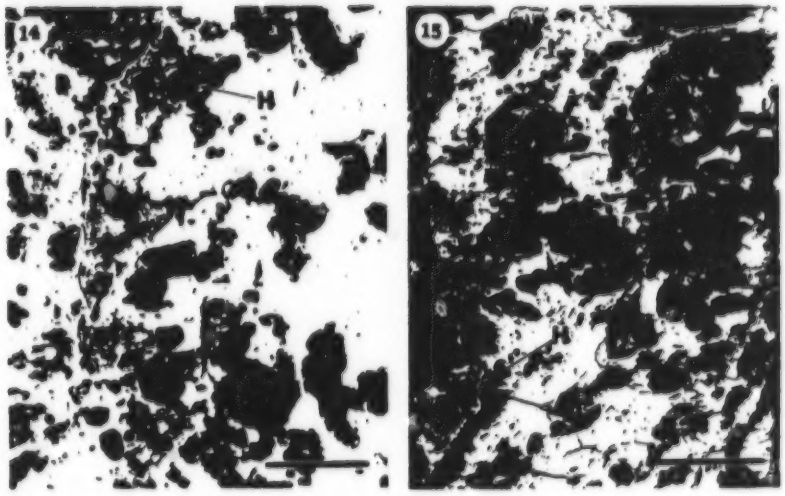


Fig. 13. Photograph of drill-core with 4-cm diameter spherical structure. Black areas are vugs.

Fig. 14. Massive pyrite-marcasite (white) and hercynite (H) within the spherical structure. (6R007005x, optical photomicrograph, scale=0.25 cm).

Fig. 15. Partly banded pyrrhotite (white) and hercynite (H) outside the spherical structure. (6R007005x, optical photomicrograph, scale=0.25 cm).

sample, mainly associated with the silicates. Quartz was also identified.

The pyrite-marcasite facies consists mostly of pyrite with subordinate marcasite and minor disseminated pyrrhotite. Chalcopyrite is a minor phase only present in the silicates and molybdenite is a trace constituent in pyrite. Some cobaltite is in contact with pyrite but only on the periphery of the circular structure.

The pyrrhotite facies shows lamellar alignment of grains or banding in places; a feature also paralleled by some of the graphite. Chalcopyrite is a minor constituent, occurring principally as 20-50 micrometre inclusions in pyrrhotite. Marcasite, molybdenite, cobaltite and pentlandite are rare to very rare and single grains of loellingite, Bi-Te and Se-bearing galena were also found.

No PGM were found but PGE were detected in both the larger cobaltite grains (100 - 150 micrometres) (Fig. 16) and the smaller ones (<50 micrometres) as shown in Figure 17. Complete quantitative electron microprobe analyses for some cobaltite grains are given in Table 3.

Table 3. Electron microprobe analyses of cobaltite (wt.%)

	Co	Fe	Ni	Pd	As	S	Totals
1.	21.8	5.6	7.5	0.08	46.1	17.8	98.88
2.	22.2	5.4	7.8	0.08	46.9	18.2	100.58
3.	29.8	2.8	3.0	n.d.*	43.5	19.7	98.8
4.	23.1	5.6	6.5	0.06	45.9	18.7	99.86
5.	30.1	3.1	3.3	n.d.	44.6	20.0	101.1
6.	28.7	3.9	3.2	0.03	45.2	18.7	99.73
7.	23.6	5.3	6.5	0.04	46.5	18.3	100.24
8.	22.5	5.5	7.2	0.04	46.8	18.2	100.24

Anal. 1-5 on large zoned cobaltite grains and Anal. 6-8 on the smaller cobaltite grains; Sb not detected. *n.d.=not detected MDL for Pd=0.02 wt.%, for Pt=0.04 wt.% and for Sb 0.02 wt.%.

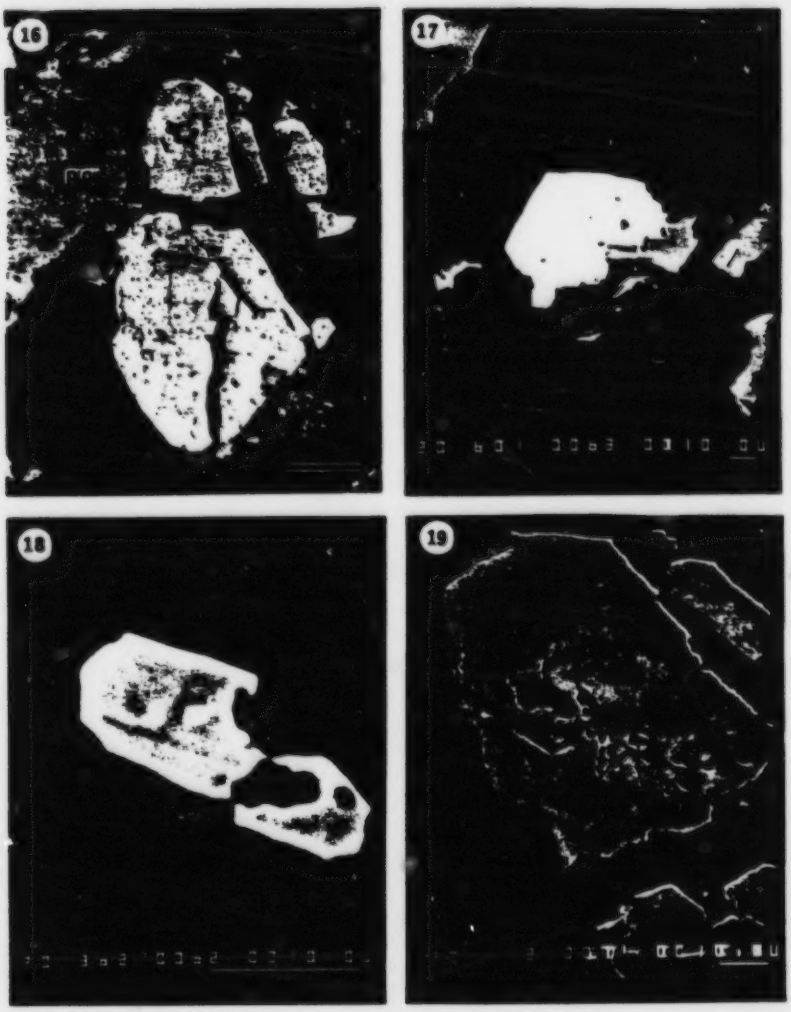


Fig. 16. "Large" cobaltite grains (light grey) attached to pyrrhotite (po) surrounded by quartz and silicates (Si>Fe = Al = Mg). (6R007005x, optical photomicrograph, scale=40 micrometres).

Figs. 17,18. "Small" PGE-bearing cobaltite grain (white) attached to pyrrhotite (grey) and included in quartz (17). A cobaltite grain (grey) with a Bi-Te inclusion (large white spot) and a smaller spot of high Pt content all included in silicate (Si>Mg=Al=Fe), 18. (6R007005x, SEM photomicrographs).

Fig. 19. SEM photomicrograph of the top-most cobaltite grain shown in Fig. 16 to illustrate zoning. The crosses and numbers refer to spot analyses given in Table 4.

Spot analyses for Pd and Pt, given in Table 4, reveal low but consistent Pd contents. Pt was only detected in one grain (Fig. 18) and a second spot analysis on a bright (high atomic number) area had a very high Pt content (= 4 wt.%) which is interpreted as due to a sub-surface inclusion of a Pt mineral. The grains shown in Figure 16 are also given in SEM Figure 19 where zoning can be observed. The zones appear related to the major and minor elements: darker zones have lower As, Ni, Fe and higher S and Co. The Pd was only detected in the lighter zones, which have higher As, Ni, Fe and lower S and Co.

Table 4. Spot analyses for Pd and Pt in cobaltite.

Grain No.	Spot #	Association	Pd wt.%	Pt wt.%
6	1	silicate (See	0.09	<MDL
	2	Figs. 16,19,20)	0.08	<MDL
	3		0.06	<MDL
	4		0.05	<MDL
	5		0.08	<MDL
	6		0.09	<MDL
	7		0.06	<MDL
	8		0.08	<MDL
	9		<MDL	<MDL
	10		<MDL	<MDL
8	1	silicate/ molybdenite	0.06	<MDL
	2		0.02	<MDL
7	1	silicate/ pyrrhotite	0.03	<MDL
	2		0.02	<MDL
3	1	pyrrhotite/ silicate	0.03	<MDL
	2		0.06	<MDL
13	1*	silicate	0.04	0.17
15	1	pyrite/ silicate	0.04	<MDL
	2		0.03	<MDL

* A second spot had a very high Pt value (= 4 wt.%), thought to be due to a subsurface Pt PGM (see Fig. 18).

Sample 6R007014x

This sample consists of two rock types, one containing reddish silicates (pink and white orthogneiss?) and the other heavily disseminated with sulphides (Fig. 20). The major sulphide is marcasite which either is massive or surrounds large pyrite crystals. Some pyrite veins the silicates. Graphite is a minor constituent and traces of chalcopyrite and molybdenite occur in marcasite, while traces of chalcopyrite and pyrrhotite were found in pyrite. A few coarse concentrations of chalcopyrite (up to 1 cm) occur in the transition zone as well as four 20-40 micrometre grains of galena found included in silicates. Some trace element analyses for Ni in marcasite and pyrite were done in order to establish the source of the high Ni assay value. Nickel was determined to occur in the marcasite away from the transition zone (0.13 to 1.95 wt.% for seven spot analyses). Surprisingly, the pyrite contained no Ni but had high Co contents (about 2 wt.% for 3 grains). No PGM were observed and no trace-element PGE analyses were carried out.

Sample 6R01002x

The rock consists of 80-90% massive sulphide (Fig. 21). Pyrite is the principal sulphide in the area cut for the polished section, and varies from massive to disseminated crystals in the gangue (quartz, spinel, graphite and a vein of calcite were identified). Other parts of the sample, not examined, appear to be pyrrhotite-rich. Marcasite and pyrrhotite are minor phases in the pyrite, and chalcopyrite and molybdenite occur in trace amounts. Three <50 micrometre cobaltite grains were found (in

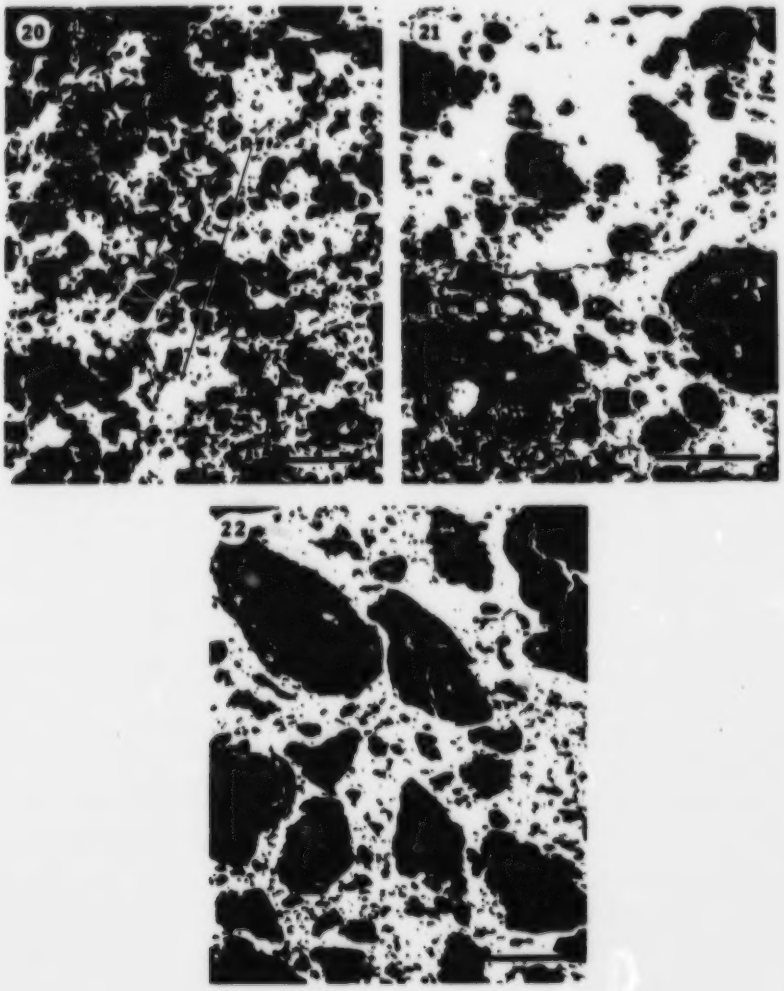


Fig. 20. Pyrite (py) in a marcasite matrix (white). (6R007014x, optical photomicrograph, scale-0.25 cm).

Fig. 21. Massive pyrite (white) and rounded silicates. (6R01002x, optical photomicrograph, scale-0.25 cm).

Fig. 22. Pyrite matrix (white) with graphite-bearing silicate fragments. (11020W-C, optical photomicrograph, scale-0.25 cm).

quartz, calcite and unidentified silicates) as well as a single grain of Bi-Te. A group of rutile crystals was also observed. No PGM were identified and no trace-element PGE analyses were carried out.

Sample 11020W-C

This rock appears to be a micro-conglomerate set in a sulphide matrix (60/40:sulphide/silicate) or a transported breccia (Fig. 22). The silicate "pebbles" attain 1.5 cm in length and appear to be similar in composition and graphite-rich. Ilmenite is a trace constituent of the gangue, occasionally containing rutile inclusions. The sulphide is massive pyrite with traces of marcasite. No PGM were observed.

DISCUSSION

Assays were provided for three samples and the values for Cu and Ni are consistent with the mineralogy. In addition, Co was found to occur in unusually high concentrations in the pyrite of sample 6R007014x. Platinum and Pd, occurring together or separately, were directly confirmed by EMP analyses in three samples (6R018003x, 6R015017x and 6R007005x) despite the fact that discrete PGM were not found. These PGE occur in the form of a solid solution in cobaltite and Pd alone also occurs in melonite. Platinum and Pd have been reported in cobaltite from several other deposits and deposit types (Cabri & Laflamme, 1981, 1984). Palladium assays, given for two of the three samples in which Pd was found mineralogically, are

relatively consistent with the Pd distribution though it is not possible to be quantitative. On the other hand, the high Pt assay value for 6R018003x is not compatible with the mineralogy. The trace Pt determined in cobaltite cannot entirely account for that assay value. There was insufficient material to perform reliable assays of mineral separates except for the -100+200 mesh fraction of silicates floated with 3.3 S.G. liquid (i.e., silicates except for hercynite). The assay results were at the detection limits, i.e. < 0.2 ppm Pt and < 0.1 ppm Pd, but sufficiently low to confirm that the bulk of the Pt is not associated with the lighter silicates. We are reasonably confident that we have not missed finding discrete Pt PGM and therefore the only way to account for that assay value, if correct, is with the presence of a dilute solid solution of Pt in another mineral. For example, as little as 10 ppm Pt solid solution in a mineral as abundant as pyrrhotite would account for the Pt assay.

Definitive observations on paragenesis are difficult to make because no petrography was done and the ore mineralogy was done on a very limited suite of samples. In addition, different rock types and facies are represented. The mineralogy of the most intensely studied sample, 6R018003x, corresponds to the high amphibolite metamorphic grade but it is difficult to determine whether this represents an originally pelitic rock or whether it represents a pre-metamorphic alteration associated with the sulphide mineralization. The sillimanite could have formed metamorphically or by leaching of older silicates. The origin of the graphite is unknown, but it is likely

to be of inorganic origin. The hypersthene-rich sample (6R015017x) is a mafic rock rich in sulphides which, no doubt, are closely related to the original intrusive rock.

CONCLUSIONS

Three of the six samples have measureable trace quantities of Pd and Pt in minerals such as cobaltite and melonite (Pd only), though no discrete PGM were found. These three samples are pyrrhotite-rich when compared to the predominant pyrite or marcasite-pyrite in samples where no PGE were found. This tentative correlation may be used as a prospecting guide.

The single micro-inclusion of native gold in chalcopyrite suggests that gold may be concentrated and recovered with copper. Further observations are required to confirm this suggestion.

The bulk of the Ni occurs in solid solution in pyrrhotite, the remainder occurring as very fine-grained Ni minerals (pentlandite and violarite) included in pyrrhotite, which therefore, cannot be easily liberated. In one sample the Ni occurs principally in marcasite. Thus, potential Ni recovery can only be contemplated from pyrrhotite or from marcasite concentrates: both would be high in sulphur content. All the Cu occurs in chalcopyrite and, in all but one sample, can be liberated at a grind of -325 mesh.

The rock types are compatible with high amphibolite metamorphic grade and some could represent mafic members related to the small stratiform ultramafic bodies reported to occur sporadically throughout the area (Culshaw, 1984).

RECOMMENDATIONS

Further work is warranted to investigate the following:

(1) More analytical work to better define the Ni and Co distributions in samples such as 6R007014x.

(2) Determination of the PGE distribution by more detailed mineralogical investigations of PGE-rich material using larger samples. This will permit better assessment (because of sample heterogeneity) and also permit assays with lower detection limits (on carefully prepared mineral separates).

ACKNOWLEDGEMENTS

K. Besso and P. Carrière performed X-ray diffraction analyses, P.Moloughney provided assays, M. Beaulne made mineral separates and D. Leblanc prepared the polished sections.

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